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METHOD AND COST OF MINING HEMATITE AT THE EUREKA-ASTEROID MINE ON THE GOGEBIC RANGE, GOGEBIC COUNTY, MICH.

BY

O. M. SCHAUS

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METHOD AND COST OF MINING HEMATITE AT THE EUREKA-ASTEROID MINE ON THE GOGEBIC RANGE, GOGEBIC COUNTY, MICH[1]

By O. M. Schaus[2]

INTRODUCTION

The following is a description of the methods employed at the Eureka-Asteroid mine, which is situated on the Gogebic range, at Ramsay, Mich. The mine is operated by the Castile Mining Co. under the direction of Oglebay Norton & Co.

This paper has been prepared in accordance with an outline furnished by the United States Bureau of Mines, and is one of a series on mining methods and costs covering the principal mining operations throughout the United States.

ACKNOWLEDGMENTS

The author acknowledges the assistance of the mining organization of the Castile Mining Co. in the preparation of this paper.

HISTORY

Ore was discovered at the Eureka mine in 1890 in a crosscut from a shallow prospect shaft, now known as No. 2 shaft, which is located near the west end of the property. Production in 1890 was 23,794 tons. Shipments were continuous until 1896. The mine did not operate again until 1906 but has produced regularly since that date.

The present operators obtained control of the Eureka and Asteroid mines in 1906 and operated them as separate units until 1926. They were then connected underground and consolidated as the Eureka-Asteroid mine, with the production from both mines hoisted through the Eureka No. 4 shaft.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6348."

[2] One of the Consulting Engineers, U. S. Bureau of Mines; Assistant Range Manager, Ogleboy Norton & Co.

GEOLOGY

The iron formation in this part of the district consists of alternate layers of cherty horizons and slaty horizons lying upon a footwall of quartzite and overlain by siliceous slates known as the Tyler slates. The formation dips 55 to 75°, strikes about east-west, and is intersected by a series of igneous blankets or diorite dikes, approximately normal to the bedding. In the troughs formed by the intersection of the footwall or other impervious slate bands the important ore bodies occur. In the Eureka mine there are many faults that displace the beds, in some cases as much as 600 feet, frequently 100 feet. They have almost every conceivable dip and strike, sometimes apparently aiding in the making of ore bodies, other times serving to prevent ore occurrence. Figure 1 shows a generalized cross section through this range, and Figure 3 shows a generalized longitudinal section.

PHYSICAL CHARACTERISTICS OF ORE AND INCLOSING ROCKS

The ore is a soft red hematite that requires the support of timber in all openings. At the top of the footwall is a band of soft red slate, shaly where adjacent to the ore bodies, which readily slabs off and is a constant menace in its contaminating effect on the ore. The hanging wall or capping is usually cherty iron formation, and the contact between capping and ore is very irregular. The hanging rock is ordinarily strong enough in itself to stand without support, but due to its irregular outline blocks are left isolated or weakened by mining the pockets of ore, and these slab off after the ore is removed.

Two types of ore bodies are found in this mine. One type, which is most typical of the district, consists of masses triangular in cross section lying at the intersection of the diorite dikes with the footwall. The other type consists of narrow blankets 5 to 20 feet in width lying on the footwall. Both types produce what is known as Old Range Non Bessemer grade iron ore. Bessemer-grade ore is produced at some of the mines in the district, and a considerable tonnage has been shipped from this mine; but in order to produce two grades economically, they must be found in separate ore bodies or in large enough masses within the same ore body to warrant separation.

GENERAL ITEMS PECULIAR TO DISTRICT

The Gogebic range is a well-established mining center, having many advantages which may be considered ideal:

There is a liberality of thought on the range which encourages the interchange of ideas among the operating companies.

The climate is moderate.

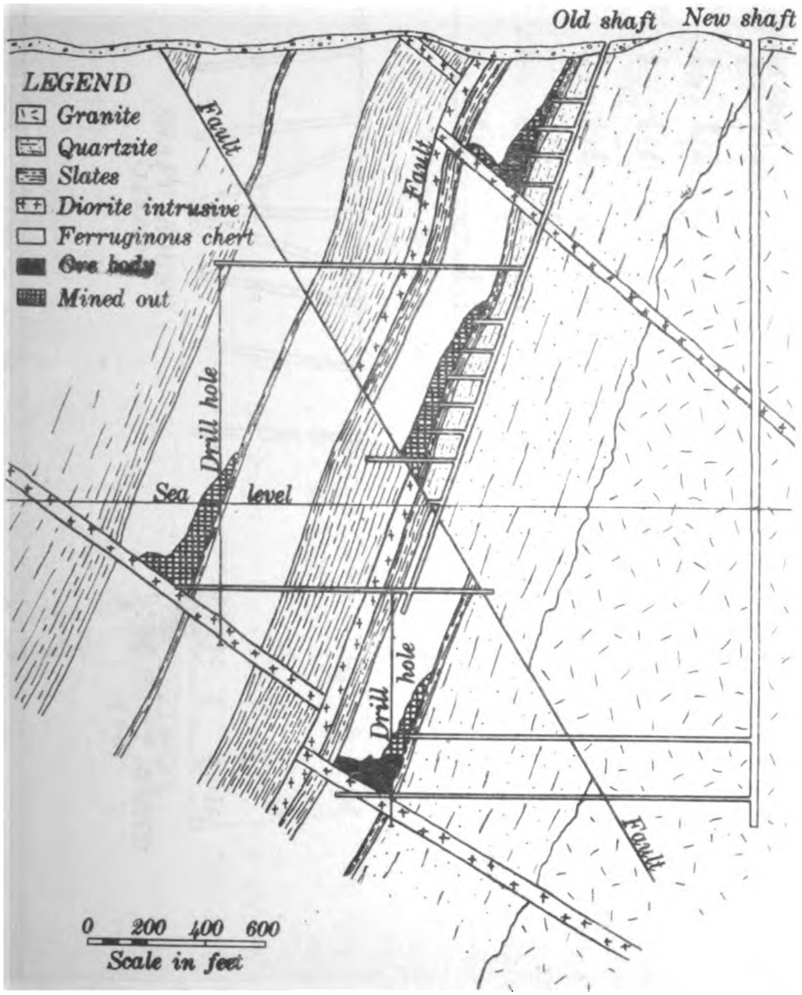
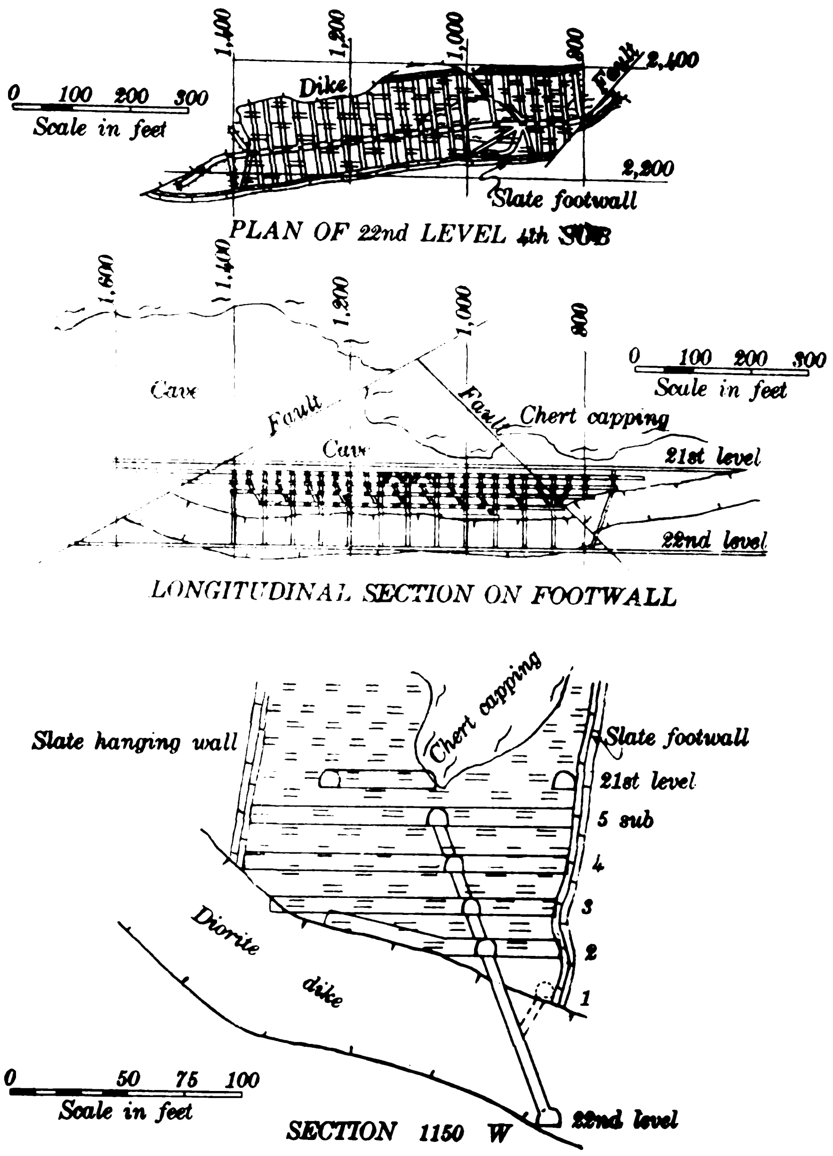


Figure 1. – Typical cross section of a Gogebic Range mine


PLAN OF 22nd LEVEL 4th SUB

LONGITUDINAL SECTION ON FOOTWALL

SECTION 1150 W

Figure 2. – Sections showing methods of developing ore body

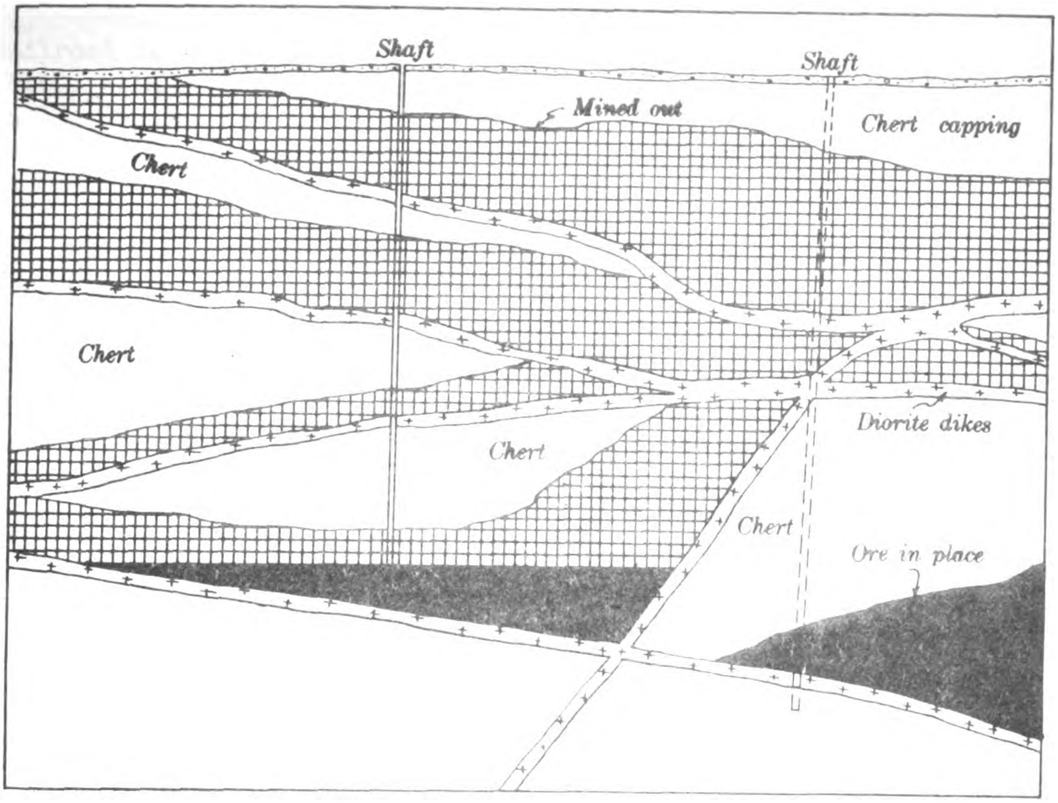


Figure 3. – Typical footwall longitudinal projection of a Gogebic Range mine

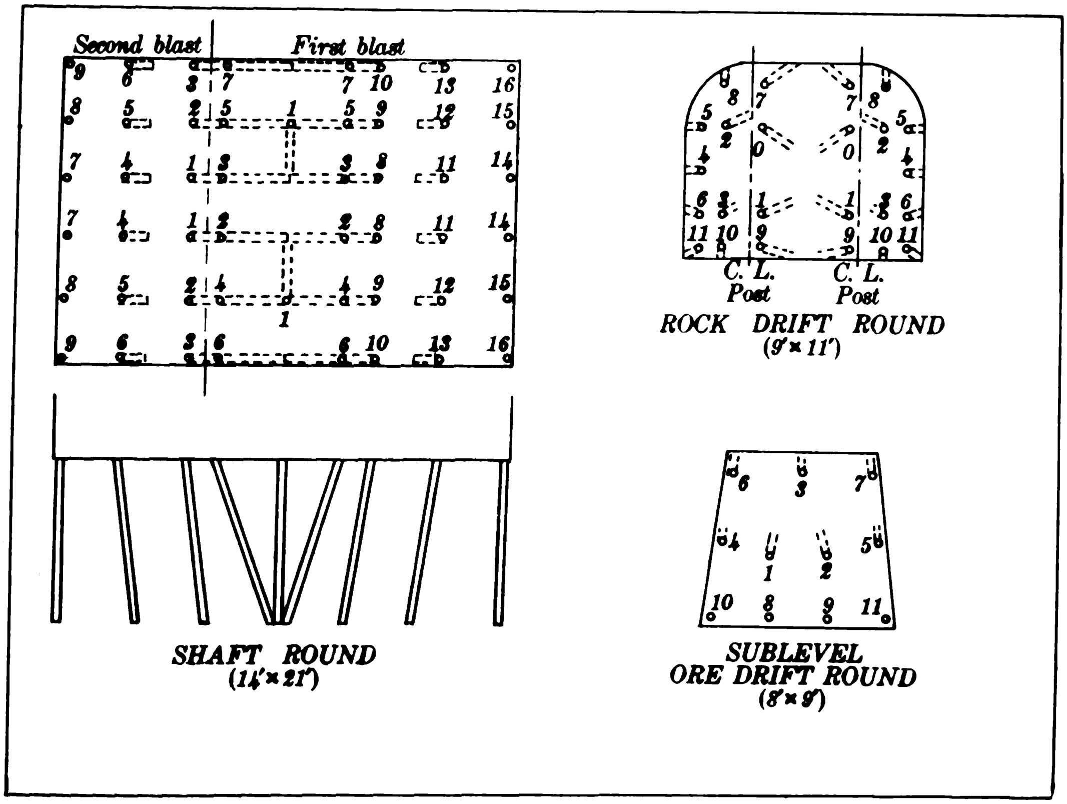


Figure 4. – Typical shaft and drift rounds

Railroad transportation is excellent. The range is located 40 miles from Ashland, Wis., a lake port. The bulk of iron ore from the Lake Superior region is shipped on the Great Lakes to lower lake ports. As navigation is closed during the winter months it is general practice for underground mines to stock their production for five months of the year.

The industry is on friendly relations with a good class of labor for all branches of mining.

Timber and miscellaneous supplies are near at hand. Regular equipment generally adopted throughout the Lake Superior iron ore region can be used here.

Electric power is available in a plentiful and dependable supply.

Pumping is not a serious problem and water for drinking and sanitary purposes is conveniently available throughout the district.

METHODS OF PROSPECTING AND EXPLORATION

Exploration and prospecting on surface is conducted mostly by means of churn drills and diamond drills. Practically all exploration at present is carried on underground by diamond drilling and exploratory crosscuts and drifts. Common procedure in underground exploration is to drill a hole paralleling the footwall from the bottom level for the purpose of locating lower dikes and obtaining additional data on faulted structures. If such a dike is found at a reasonable depth the shaft will be sunk to a point opposite the intersection of the dike with the footwall. With the shaft sunk to this depth a crosscut will be driven to the dike and exploratory work conducted along the intersection which is the most favorable place for the occurrence of ore bodies.

SAMPLING AND ESTIMATION OF ORE RESERVES

The ore is distinct from the waste, and its iron content is very uniform throughout a given ore body. The phosphorus content, however, which determines the grade of the ore, is sometimes quite variable within a given ore body, and when both Bessemer and Non-Bessemer grades are being produced, the services of a good sampler are necessary.

In development work the breast of each heading is sampled by the shift boss after each blast. The results of these samples plotted on the analyses maps are studied by the management when planning the extraction of the ore.

Estimates of ore reserves are required once each year by the State Tax Commission for valuation purposes. A method of valuing ore reserves known as the Finlay system is required of the mining companies. According to this system ore above the lowest developed level of the mine is called "Developed Ore" and is estimated by means of cross-sections in the ordinary way. Ore below the bottom level is called "Prospective Ore" and the cubical content is arrived at by projecting the bottom level ore area downward a distance of 100 feet or to such a depth as is definitely indicated by structural conditions. Ten cubic feet of ore in place is usually considered equivalent to one long ton.

MINING METHODS

General Development

In recent years operators have favored vertical shafts sunk in the footwall in preference to the inclined type sunk along the footwall, as was the practice heretofore. The reason for this is that the vertical shaft permits greater hoisting speed, less upkeep and when located well in the footwall a greater degree of safety from the effects of subsidence.

At this mine haulage levels are cut at 200-foot intervals. Each haulage level however, presents a different problem, and the plans for developing a new level are usually determined by information gained on the level above.

Three primary factors govern the layout of a proposed haulage level: First, the location of ore bodies; second, geological conditions; and third, maintenance of communication with another outlet shaft.

The iron formation or ore horizon is about 1,000 feet thick, strikes about east-west, and dips about 70° to the north. Ore bodies may possibly be found any place in the lower 200 feet or the upper 500 feet of the iron formation. The intermediate member is a slaty horizon that is unproductive. Ore bodies in the lower member are called "foot ore bodies" and those in the upper member, "hanging ore bodies". The production shaft is vertical and at the depth of 2,000 feet is about 1,000 feet south of the footwall and half way between the east and west property lines. The second outlet is an inclined shaft 2,000 feet east of the production shaft. This shaft is sunk to a depth of 1,700 feet and the hoisting shaft to a depth of 3,275 feet. Connections between the two are made by drifts and raises in rock that can be maintained indefinitely.

Obviously a considerable amount of exploration must be carried on to locat ore bodies in such a large formation. The intersections of dikes with the footwa and other slate members within the formation are, with a few exceptions, the only points worthy of exploration.

The development of each ore body is also a separate problem for the reasons that they are irregularly located, are irregular in outline, and range from pockets of a few thousand tons to bodies containing a million or more tons. At present all ore bodies are developed to be mined with the sublevel caving system. The discovery of an ore body on a new level necessitates such developmen by raises, crosscuts, and drifts, as will definitely outline the limits of ore. When the limits of ore have been determined by the preliminary development a systematic development program can be started with the spacing of openings strategically planned utilizing as many as possible of the preliminary openings a can be fitted into the mining scheme.

The discovery of an ore body by diamond drilling usually permits its outlines to be determined well in advance of development work, and often one haulage level can be so located as to handle the production from the entire ore body.

The vertical spacing of sublevels is from 18 to 25 feet. The narrow ore bodies are given the greater interval between subs in an endeavor to approach the caving production per foot of sublevel development that is obtained in the wider ore bodies. The spacing of raises varies considerably with the width of the ore body. Where the ore occurs in narrow veins or blankets on the footwall the raises are spaced as much as 200 feet apart. Such raises have two compartments, one serving as a manway and supply raise and theother as an ore pass. In ore bodies 100 feet wide and upwards the double raises are sometimes spaced at 50-foot intervals with one compartment, branch raises splitting the pillar. Ore bodies 5 to 50 feet in width are developed on sublevels by means of drifts, and wider ore bodies are developed by crosscuts spaced at 25-foot intervals with one connecting drift through the raises as indicated in Figure 2.

Shaft Sinking

The hoisting shaft at this mine is arranged with six compartments consisting of two skipways, two cageways, a pipeway, and ladderway. Seven-ton skips are operated in balance, as are the cages. At the present time only one cage is used with a dummy in balance. The headframe is arranged with dumps for four skips, so that additional skips can be operated in the two cage roads, thus permitting the capacity of the shaft to be doubled on short notice.

The shaft is of all steel and concrete construction. Six-inch, 22.5 pound per foot H-beams form the wall plates and dividers. Sets are placed at 6-foot intervals suspended by twelve $2\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{1}{2}$ inch angle studdles. Reinforced-concrete lath plank of the dimensions $2\frac{1}{2}$ by $8\frac{1}{2}$ inches by 5 feet 11 inches are used to lag the sides between the sets. Ninety lath are stood vertically around the perimeter of the shaft to lag one set of steel. The lath are held in place by small angles riveted in between the flanges of the H-beams. One and one-half inches reinforced lath plank are used to box in the man way and skip ways between hoisting levels. Corner blocks, to keep the sets in permanent alignment, are made of soft concrete in cement sacks which are inserted at intervals between the shaft steel and wall rock and then allowed to set. Wooden corner blocks are used to temporarily align the sets before the concrete blocks are installed. Twelve-inch I-beams hitched and concreted into the wall rock are used as bearing pieces which are installed below the skip chairs on each level. When sinking through ground that tends to spall off the walls are gunited before the lath plank are installed. When the shaft is sunk to the elevation of a new level about 15 feet of station is cut on each end of the shaft, and the excavation for the pocket is sunk along with the shaft. This method of cutting pockets has been found quite economical because all heavy blasting is done from 20 to 30 feet below the last shaft set, thus obviating any injury to the sets and permitting construction of the pocket to be started as soon as the sets are installed.

Shaft sinking is run on a 3-shift basis, with nine miners and a shift boss on each 8-hour shift. These men work on a contract system of $60.00 per foot of shaft, with a minimum rate of $6.00 per day. The shift bosses on shaft work participate in the contract and receive 50 cents per day more than the miners.

Hand-held sinking machines with chucks for 1-inch hexagon hollow steel are used in shaft sinking. The drill bits are the 4-point straight-face type, with a double taper of 5 and 14°.

An average cut in granite breaks about 7 feet, and a complete cycle covers about 41 hours. The opening is 14 by 21 feet. Figure 4 shows the arrangement of holes in a shaft round. The entire round is drilled, and the cut holes and one end are blasted first. This rock is then mucked out and the remainder of the holes blasted. Depending on the nature of the ground, the shaft sets are carried from 10 to 24 feet behind the breast. Round tamarack poles are chained to the under sides of the dividers to protect these from the blast. All sets when installed are completed with concrete corner blocks and lath plank.

Eighty per cent gelatin powder in 1-inch diameter cartridges is used in shaft sinking, with electric blasting caps and delay igniters.

A combined cage and crosshead for shaft sinking was recently developed at this property to meet the demands of safety and economical transportation of material to the bottom of the shaft. In case of a broken hoisting rope the cage will stick to the guides by means of the safety dogs, and the bucket can not drop because it is held to the cage by suspended hooks. The last set of steel is equipped with movable stop blocks, which stop the cage and permit the bucket to go to the bottom of the shaft. The bucket is also released from the cage at the dump, after the dump chute is in place, by means of a simple bumper or chair controlled by the bucket landers.

When the shaft is bottomed at a level, preparations are usually made for sinking the next lift. A small opening, 5 by 6 feet, is sunk approximately in the center of the shaft for a distance of about 20 feet for a pentice. The opening is then widened out to the full size of the shaft, and two shaft sets are concreted in place. This permits the next lift to be sunk without any interruption to other operations in the mine.

Drifting

Main level drifts where timbered are about 9 by 11 feet in cross section. Eight-foot posts and caps are used with about a 2-foot rake on the posts. Round timber is used entirely for drift sets and raise cribbing. Drift sets are placed at 5-foot centers, and the sides and back are lagged with 6-foot split-cedar lagging. All drifts in ore are timbered and all timbered drifts are fore-poled. Untimbered haulage drifts are about 8 by 10 feet in cross section. Sublevel drifts use 7-foot timber and are about 8 by 9 feet in cross section. Scrapers are used for mucking in all drifts. In sublevel drifts the muck is scraped into raises, and in main level drifts portable scraper slides are used and the muck is scraped into 60- cubic foot rocker-dump cars. Portable slide has replaced all power shovels formerly used in this work because of their lower initial and maintenance costs, and simplicity of operation. Untimbered rock crosscuts have been advanced from 800 to 900 feet in a month with these slides, during which period the maintenance costs are almost negligible.

Drift miners receive a contract rate per foot of drift with powder furnishe by the company. Untimbered rock drifts are driven for $6.00 per foot, timbered drifts $6.50 per foot, and sublevel drifts $2.50 to $3.00 per foot. The minimum or company account rate of pay for miners is 58 cents per hour.

Ore drifts are driven with hand-held auger machines, using auger steel. In rock drifts mounted 4-inch water-hammer machines are used with 1¼-inch hollow round steel. Figure 4 shows the arrangement of holes for various drift rounds used at this mine. All main level drifts are blasted with electricity, but fuses are used on the sublevels as electric blasting circuits can not be maintained with safety in these places.

The most recent rock heading that was advanced any considerable distance was that of the 24th level shaft crosscut, which was driven during November and December, 1928. This crosscut was 1,250 feet in length and was driven through granite, quartz slate, massive quartzite, and some iron formation. An advance of 924 feet was made in 31 consecutive days in this heading, which was 9 by 11 feet in cross section. A small portion of this was timbered through a fault zone.

Four 4-inch water-hammer machines were used in this heading mounted on two columns. The place was operated three shifts with eight miners on each shift. In addition to the 24 miners there was a day foreman and a night foreman, one electrician and helper, two trackmen, and two ditchmen, or a total of 32 shifts per 24 hours.

The time schedule for a cycle in this heading was as follows:

	Hours	Minutes
Rigging machines		25
Drilling 24 holes	1	40
Tearing down		15
Charge holes and blast		25
Ventilation		15
Mucking 26 - 60 cu. ft. cars	1	45
Total time	4	45

For the drilling operation two service trucks, one for drill steel, equipped with two headlights, the other an equipment truck, were brought to the end of the rails. The equipment truck had three decks, on the lowest of which were placed the air and water manifolds and line oilers. The manifolds were connected to the air and water lines by means of heavy hose which when not in use, were coiled up on the side of the truck. The middle deck was used for the drill machines and the top deck for blocking, wedges and other tools. Hose for the drill machines were coiled up and hung on the sides of the truck when not in use. The posts or columns were carried on the sides of the drill steel truck.

Raising

Raising in ore is considered the most hazardous operation in this mine, and for that reason only the most careful and experienced miners are employed in this work.

All raises are cribbed as close to the back as possible and props with headboards are used to support the back when installing cribbing and drilling. Figure 5 shows the method of starting and timbering a raise. Cribbing is provided in both 4-foot and 5-foot lengths. The ore pass is usually cribbed in long raises with 5 foot cribbing and the manway with the shorter length.

In rock and hard ore wet stoper machines are used with 1-inch hexagon steel. In soft-ore raises light hand-held machines are used with auger steel. These machines are equipped with a special stoper leg clamped to the machine.

Small single-drum air hoists are used to hoist cribbing up to the back in all raises while they are being driven. Light timber cages made of sheet steel are provided for this purpose. Where several raises in a developed area are connected on sublevels timber is hoisted for several working places through one raise. Men are not allowed to ride the timber cages as they are not provided with safety dogs, and the rope is only 3/8-inch size.

All raises over 100 feet in height are blasted with electricity, as a safety measure. Electric bells or air whistles are installed in all raises to signal from below, in order that men may ascend without danger.

All chutes are provided with steel arc gates which are operated by a hand lever. These gates are fabricated in the mine shops.

Raises are driven at angles varying from 55 to 90° from the horizontal. The ore is somewhat sticky, and raises under 60° give trouble in this particular. It is found that a slope of 65° is the most practical inclination for ore passes, and to prevent ore blocking and wear on the cribbing the ore passes are lined with 1½-inch hardwood plank nailed to the cribbing.

CAVING METHODS

In narrow ore bodies, caving is started at a point midway between raises with the maximum economical scraping distance of 100 feet. If the ore body is no wider than the drift, the back lagging is removed between two sets of timber and a 6-foot cut drilled in the back. This is blasted and the miners stand on the broken ore to drill the next cut which is fanned out parallel to the drift. Before this is blasted, three or four back-lagging poles are replaced to hold back premature runs of gob. The second cut reaches the caved sub above and the ore from both cuts is then scraped out.

Where the ore is a little wider than the drift, which is usually driven along the foot, caving is started on the hanging side to remove this ore first. Two long cuts will be blasted here and then two cuts up on the foot side. The gob is reached on the second cut. Each cut is scraped to the raise following the blast. Ore over the back of the drift becomes heavy following these operations and usually comes down with one blast. Runs of gob are held back on the foot and hanging by placing poles as side lagging. The efficiency of this method increases with the width of the ore, as less development per ton caved is required in wide ore bodies.

Figure 2 shows the scheme of sub level development for wide ore bodies and Figure 6 shows the caving method. The crosscut from the raise to the hanging is driven first and then caved back within 8 feet of the raise. The scraper hoist is then moved to that side of the raise and the crosscut driven to the foot. The foot crosscut is then caved back within 8 feet of the raise and the hoist moved so that the connecting drift between raises can be caved. After this the miners move to the next raise. Development is kept ahead so that a gang of miners on the sub below can be caving the hanging crosscut while the gang above is driving the foot crosscut. Crosscuts do not remain open long as the ground is very heavy. Drifts connecting the raises are a source of trouble in that particular and have to be retimbered before they are caved because it is necessary to keep these open much longer than the crosscuts.

Miners engaged in driving "slices" or crosscuts receive $2.50 to $3.00 per foot for this work, and when caving they receive 60 to 90 cents per 60-cu. ft. car. The lower rates prevail in the wide ore bodies and higher rates in the narrow ore bodies.

Auger steel and hand-held machines are used almost entirely in this work. Box-type scrapers with 15-hp. double-drum electric hoists is the usual equipment furnished these places, but there are several old $6\frac{1}{2}$-hp. hoists in the mine that are being used on this work. Twenty-five-hp. hoists are used in places where the scraping distance is much over 100 feet.

Underground Transportation

All haulage levels are equipped with 275-volt direct current trolley lines over which are operated 2-ton, 4-ton, and 6-ton locomotives on a 24-inch gage track. Fifty-pound rails are installed on main lines and 30 and 40 pound rails on branch lines. The grade for these tracks is usually one-half of 1 per cent. No. 4/0 trolley wire with a feeder is now the standard installation since the mine has been equipped with so many electric scraper hoists. Rail roints are all bonded and pipe lines are bonded to the rails to provide a good return and prevent stray currents which are a hazard in connection with electric blasting.

Cars used for haulage are of the rocker-dump type equipped with roller bearings and having a capacity of 60 cu. ft.

The storage pocket on each haulage level has a capacity of 150 tons. Some levels are equipped with a storage raise that empties into the pocket on the level below and provides an additional storage capacity of 500 tons. The storage pocket empties into a skip measure from which the ore can be deflected into either of the two skips.

VENTILATION

Primary ventilation in this mine is natural. The conditions for this are ideal, in that the hoisting shaft, which is the deepest on the property, is located in a valley about 125 feet below and between hills on each side, where the other shafts are located. The hoisting shaft is downcast, and the air current is split on the lower levels and very thoroughly ventilates the workings on each side of the shaft crosscuts. During July and August the temperature on the surface and underground is nearly equal, and it is often necessary to use fans to help ventilation during those months. Remote workings are mechanically ventilated throughout the year.

SAFETY PRACTICE

Safety work begins at the Oglebay Norton & Co. district office, where the management meets with the general safety council once each month to consider major problems relative to the welfare of all Oglebay Norton & Co. mines. The council is composed of the range manager, superintendents, and safety directors from all of the mines. At each property there is a central safety committee composed of the superintendent, the heads of the several departments, and the safety director. This committee also meets once each month to consider local problems and report progress on the jobs ordered at previous meetings. Minutes of these meetings are forwarded to the general safety council and discussed there.

Local safety meetings at the Eureka-Asteroid mine are held once each week both underground and on surface for miners and surface workmen, usually at noon or just before quitting time. Here individuals voice their thoughts, and the foremen and safety director give short talks. One miner is appointed underground safety inspector at each mine to serve in that capacity for a week or more when he is relieved by another.

It is the duty of the safety director to organize and keep in training efficient mine rescue and first-aid teams. This mine is equipped with five sets of breathing apparatus, and five teams of five men each are trained regularly so that each team receives a practice once every five weeks. First-aid teams receive practice in a similar manner.

I. SUMMARY OF COSTS

Name or number of mine - Eureka-Asteroid. Period covered - Year 1929.

Tons ore hoisted during period - Long tons of ore hoisted, 401,680.

Mining method - Sublevel caving.

1. Underground costs per ton ore hoisted:

	1 Labor	2 Supervision	3 Compressed-air drills and steel	4 Power cost	5 Explosives	6 Timber	7 Other supplies	8 Total
Development								
(1) In ore	$0.166	$0.009	$0.038	- -	$0.041	- -	$0.007	$0.261
(2) In rock	.031	.002	.005	- -	.018	- -	- -	.056
Mining	.246	.014	.067	- -	.069	- -	.002	.398
Transportation (underground)	.205	.011	.005	$0.077	- -	- -	.110	.408
General underground expense	.037	.002	.018	.066	- -	- -	.012	.135
Timbering	.193	.011	.001	- -	- -	.068	.006	.279
Surface expense (directly applicable to underground operation)	Included in above accounts							
Totals	.878	.049	.134	.143	.128	.068	.137	1.537

III. DETAIL OF COSTS IN UNITS OF LABOR, POWER, AND SUPPLIES

DEVELOPMENT

	Shaft sinking	Drifts and crosscuts	Drifts and crosscuts	Raises	Raises	Total
Size of excavation	21 x 14	9 x 11	8 x 10	2 compt. 5 x 9	2 compt. 5 x 9	
Timbered or not	Steel	Yes	No	Yes	Yes	
Physical Prop. of Rock	Hard granite	Med. soft ore	Hard rock	Med. soft ore	Med. hard rock	
Labor (man-hrs. per ft.)						
Breaking	16.25	3.71	4.27	4.75	9.64	7.28
Timbering	8.04	2.03	- -	3.70	5.19	3.32
Mucking	31.03	1.35	.82	- -	- -	3.39
Haulage & hoisting	6.40	1.35	.82	- -	- -	1.13
Supervision	- -	- -	- -	- -	- -	.57
Total labor	61.72	8.44	5.91	8.45	14.83	15.69
Feet per 8-hr. shift	.13	.947	1.35	.95	.54	.51
Timber and explosives						
Explosives (Lbs. per ft.)	32	8	16	7	12	
Timber B.M. per ft.		74	-	27	27	
Labor (per cent) total cost						
Labor						44 per cent
Power and supplies						34 per cent

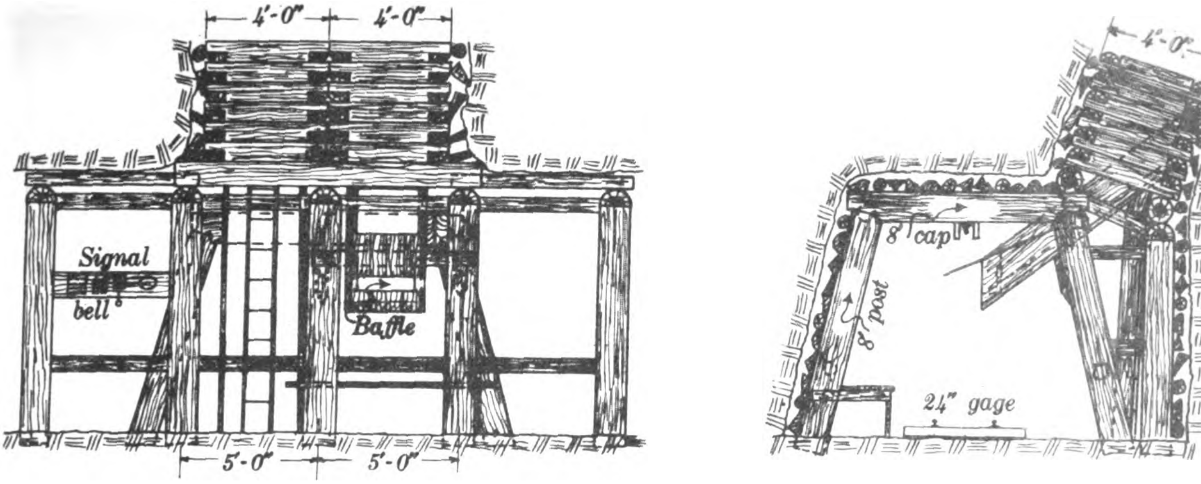


Figure 5. – Sketch of timbered raise

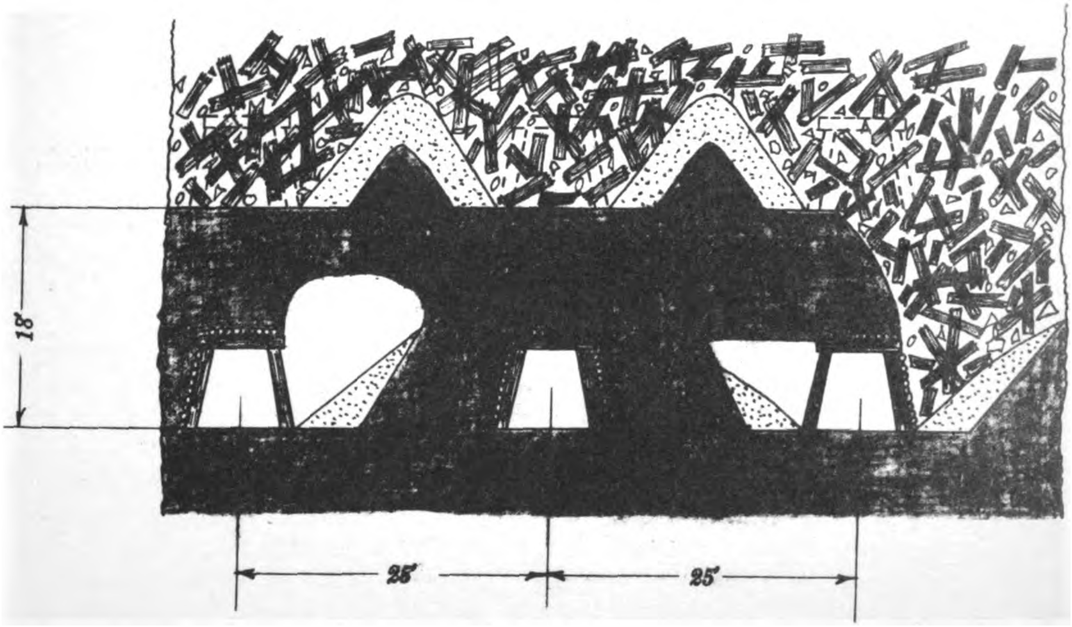


Figure 6. – Sublevel caving system. Ore scraped to raises